MTO & Heterogeneous Integration

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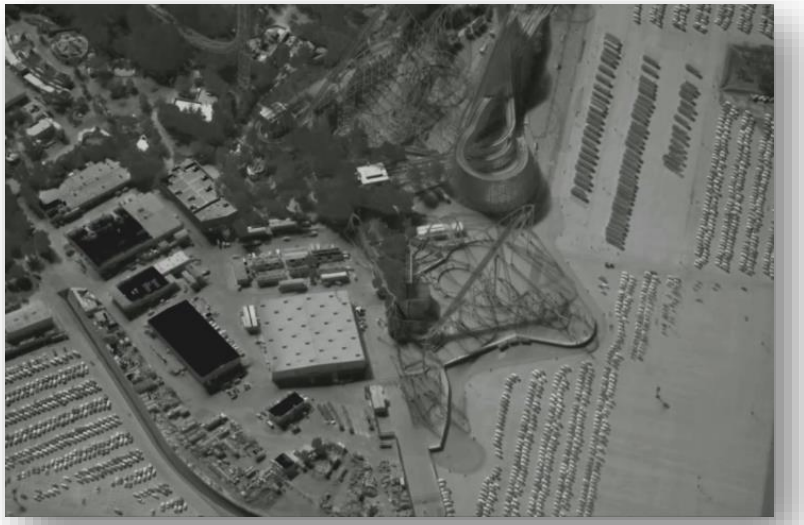
Briefing prepared for LUMOS Proposers Day

November 20, 2019

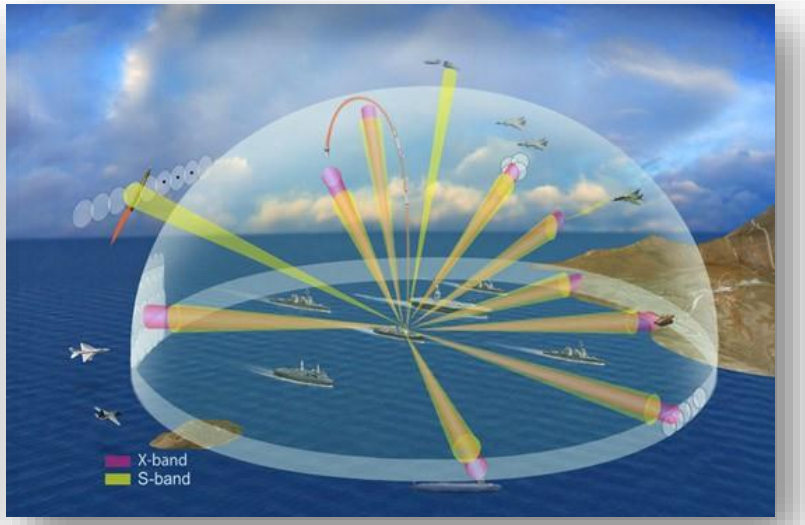
Microsystems Technology Office (MTO)

MTO's Mission

C4ISR



Electronic Warfare



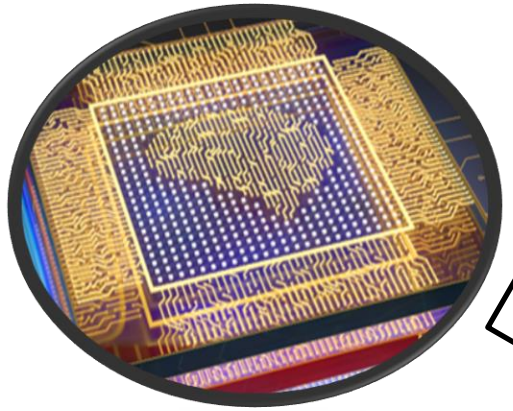
Directed Energy

MTO's core mission is the development of high-performance, intelligent microsystems and next-generation components to enable dominance in national security C4ISR, EW, and DE applications

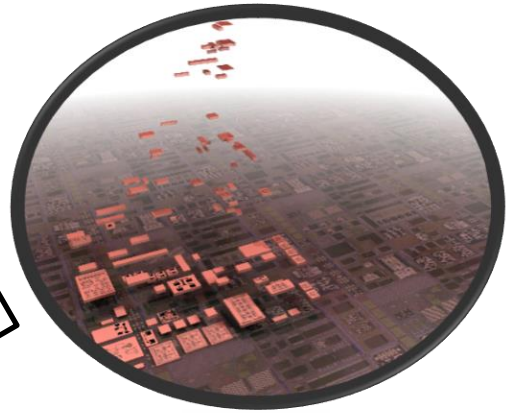
The effectiveness, survivability, and lethality of these systems depends critically on microsystems

MTO Vision

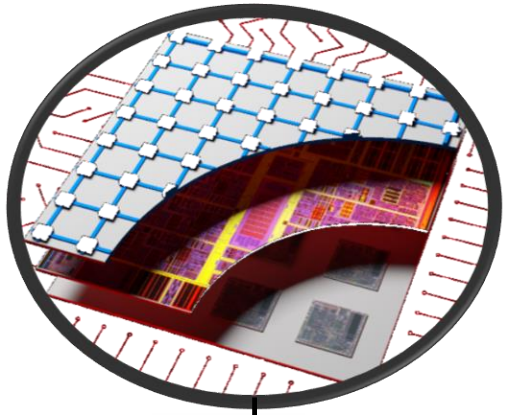
1. Embedded Microsystem Intelligence / Localized Processing



2. Next-Generation EM Components & Technologies



3. Microsystem Integration for Functional Density & Security



4. Disruptive Defense Microsystem Applications

C4ISR

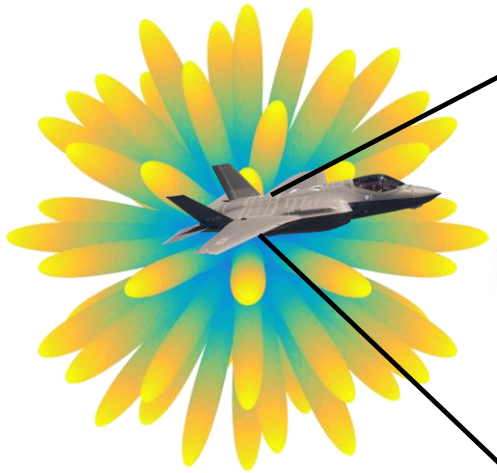
Electronic Warfare

Directed Energy

Heterogeneous Integration Millimeter Wave Digital Arrays (MIDAS)

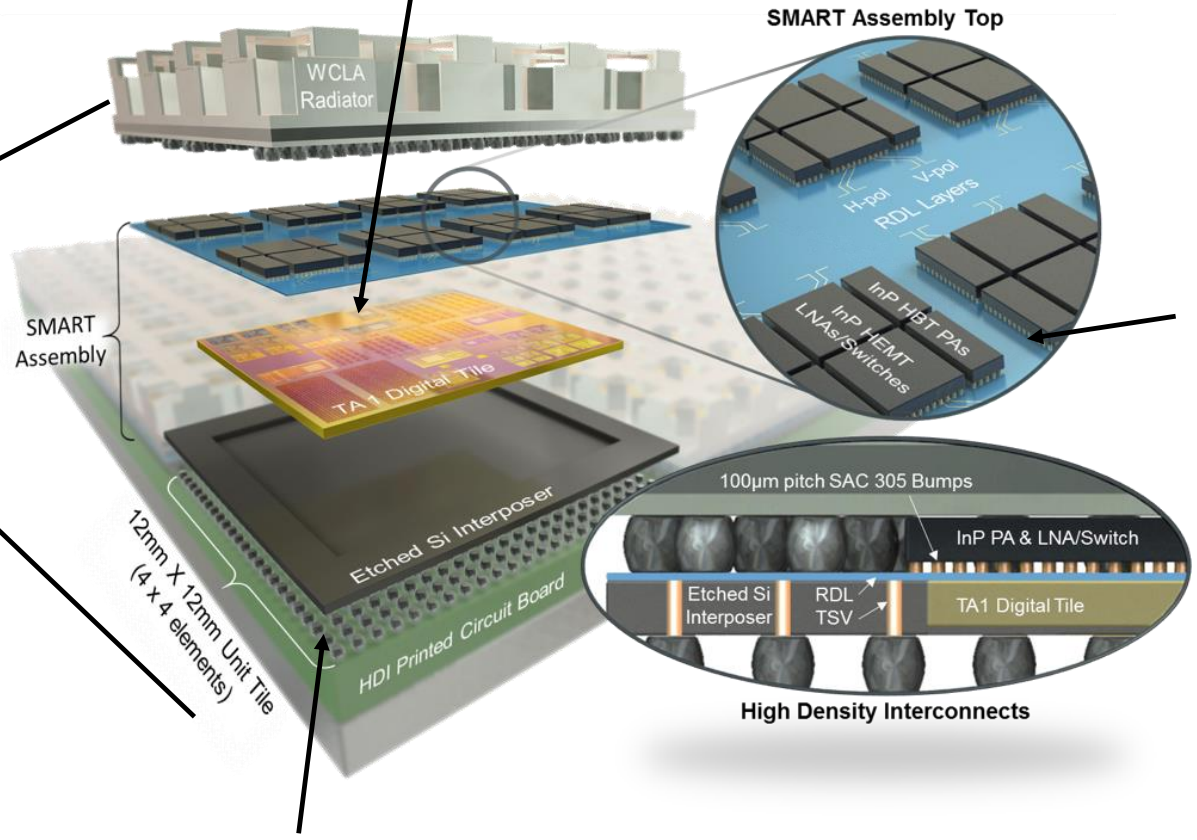
4. Disruptive Defense Microsystem Applications

Provide Full Coverage for Multi-Beam Networked Communication



- High-gain in all directions for improved network performance
- Wide bandwidth & frequency agility to adapt to future needs

1. Embedded Microsystem Intelligence / Localized Processing



2. Next-Generation Components & Technologies for Spectrum Dominance

3. Microsystem Integration for Functional Density & Security

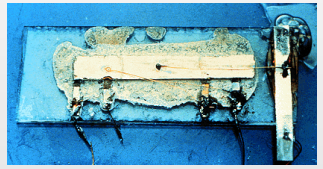
Electronics Resurgence Initiative (ERI)

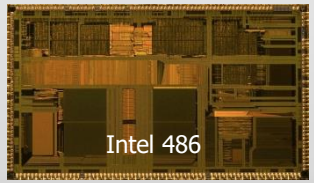
Modern electronics development waves

Device Innovations
Architecture Innovations
Design Innovations

1st Wave
Geometric Scaling

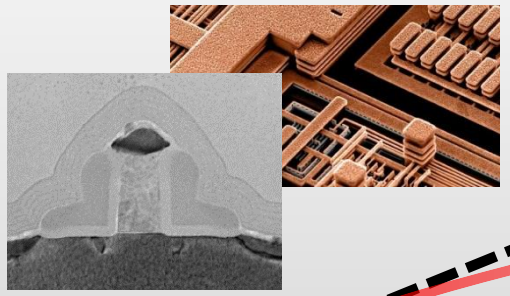
- *DUV lithography*
- *Automatic Place/Route*





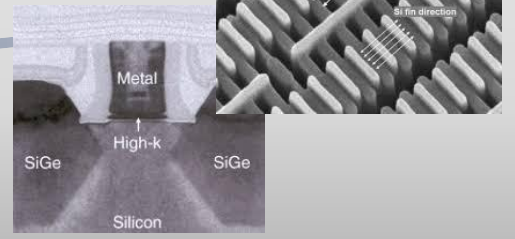
2nd Wave
BEOL Scaling

- *More scaling*
- *Low-κ/Cu interconnects*
- *Bus width scaling*
- *Logic Synthesis*



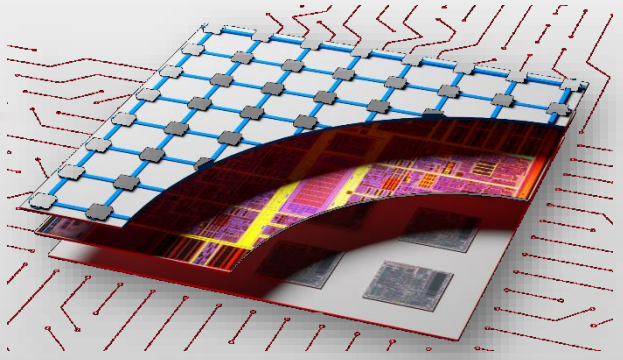
3rd Wave
3D Devices

- *Even more scaling*
- *FinFETs*
- *High-κ dielectric*
- *Strain engineering*
- *Multi-core architectures*



4th Wave
3D Heterogeneous Integration

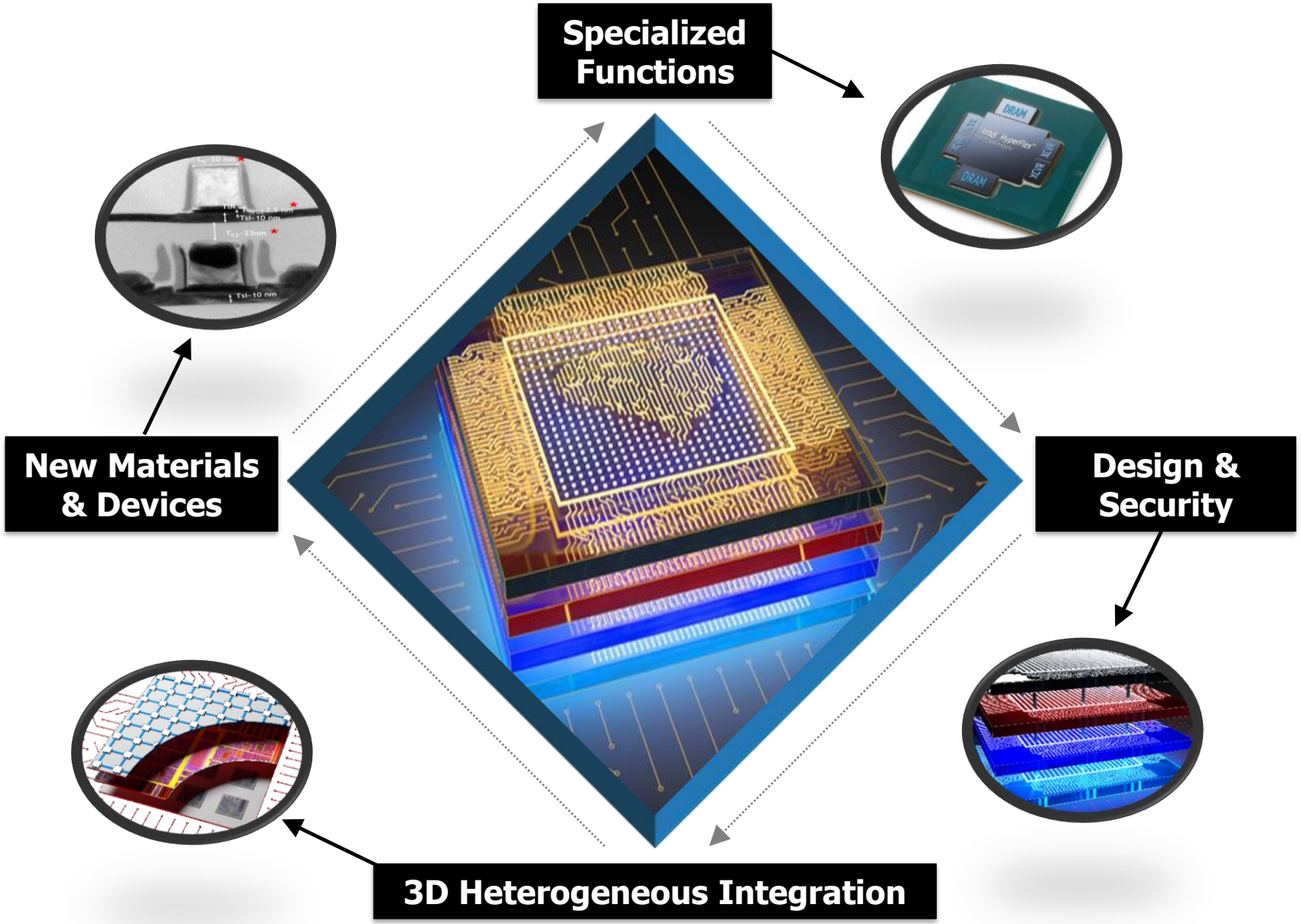
- *A little more scaling*
- *3D architectures*
- *Specialized processors*
- *Domain-specific architectures*
- *Design & security automation*



Performance, Number of Transistors

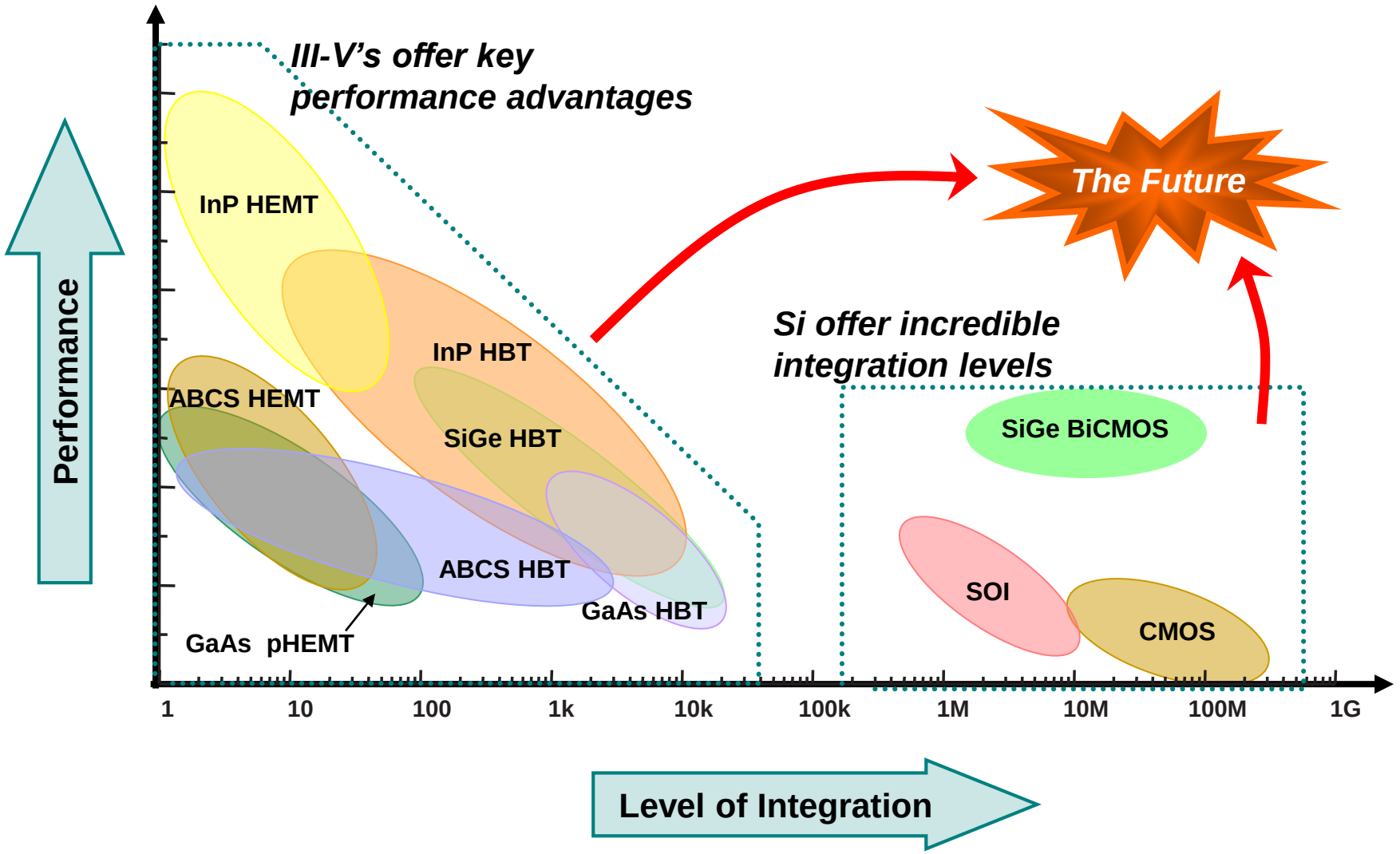
1980 1990 2000 Dennard Scaling Ends 2010 2020 2030

ERI strategy: Innovating the 4th wave



Compound Semiconductor Materials On Silicon (COSMOS)

Heterogeneous Integration Offers Best of Both Worlds



Compound Semiconductor Materials On Silicon (COSMOS)

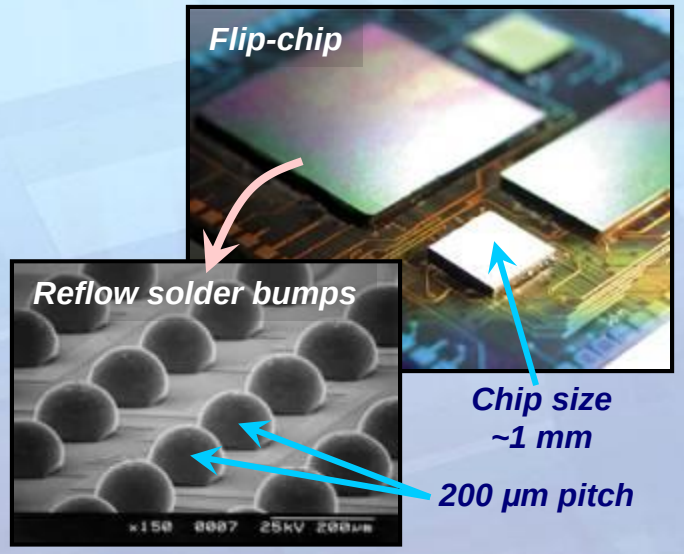
***Program Objective:* Heterogeneous integration all the way to the transistor scale**

- Enable *materials selection within circuits* – without loss of transistor performance
- Exploit existing SOA CMOS infrastructure & integration levels – without process modification

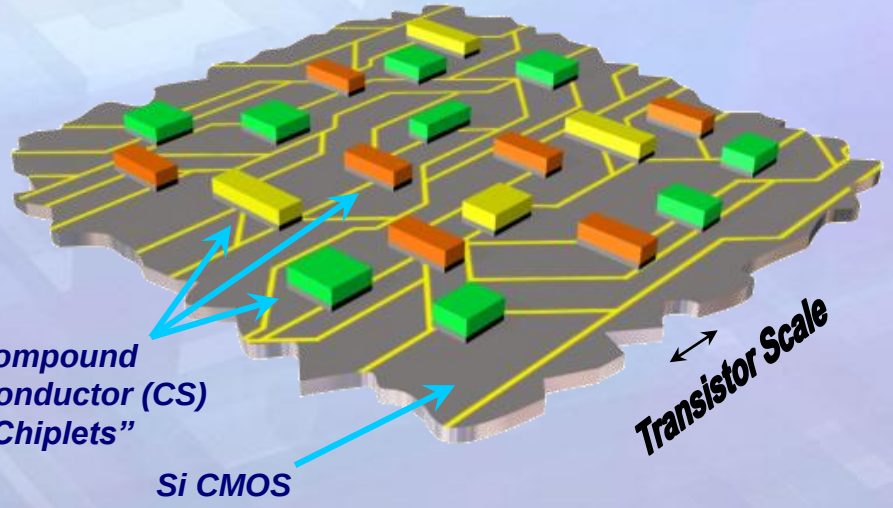
DoD Benefits

- Achieve higher functional density: *dense integration of analog, mixed-signal, & digital electronics*
- Enable circuits with lower dissipated power & far higher I/O throughput

Today



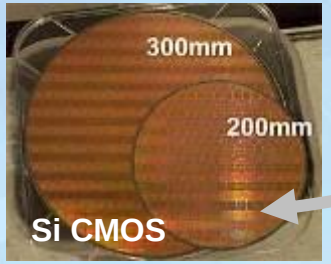
COSMOS Vision



Heterogeneous integration exists only on a very coarse scale – and not in the signal path

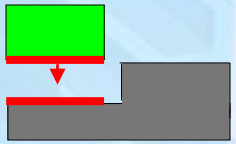
Allow the circuit designer to select the optimal transistor technology everywhere in the circuit

What is COSMOS About?



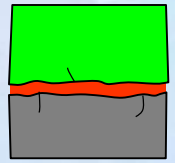
Avoid any process change

Assembly



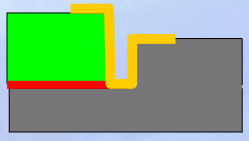
- Place (or grow) very small CS "chiplets" in exactly the right position on a processed CMOS wafer/die

Interfaces

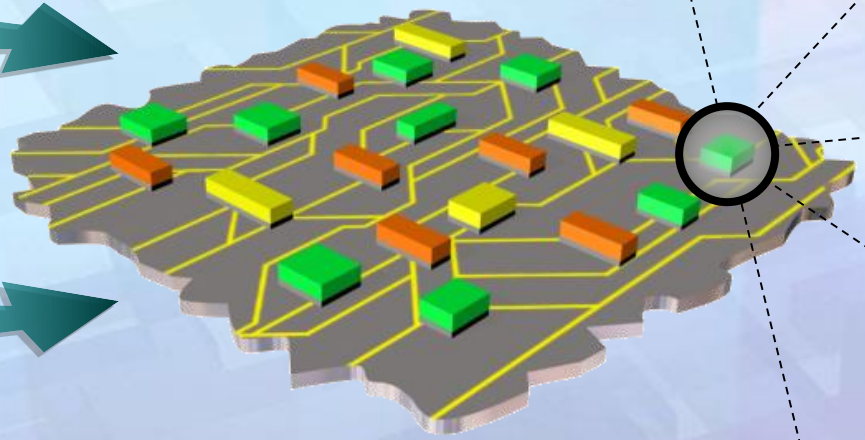


- Manage the dislocations and defects at the interfaces that could degrade transistor performance
- Accommodate CTE mismatch between materials

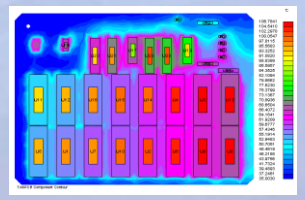
Interconnects



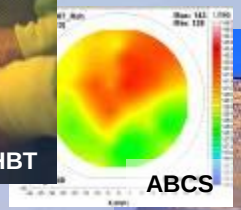
- High-density process
- Process consistent with integration approach

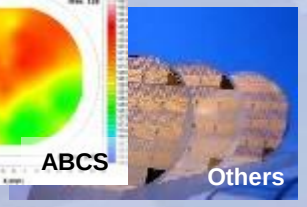


Thermal management



- Remove heat from "chiplets"





Yield

- High interconnect yield

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